MULTISTATIC ACTIVE ACOUSTICS

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LONG-TERM GOALS

The long-term objective of this research is to develop a theoretical foundation for the design of new multi-static sonar concepts for littoral seabed imaging and mine counter measures (MCM) operations. Multistatic configurations have been made possible by the development with ONR support of new inexpensive autonomous underwater vehicle technology.

OBJECTIVES

The specific objective of this project is to develop and validate theoretical and numerical models of the 3-D spatial statistics of the seismo-acoustic field produced by targets on and within a rough elastic seabed. These models are then applied to develop an improved understanding of the dominant physical processes governing the performance of moderate-to-high frequency sonar systems for detection and classification of objects above and below the seabed in shallow water environments.

BACKGROUND

The classical approach for bottom target detection and identification, is to image the bottom environment using a high-frequency, monostatic sonar system. Unfortunately such high frequency systems are achieving resolution at the cost of severely limiting bottom penetration, in turn limiting the detection of subbottom objects.

The emergence of new, inexpensive underwater vehicle platforms has created the opportunity of achieving resolution by opening the spatial aperture in multistatic configurations, in turn lowering the frequency requirements. Thus, such new multi-static sonar concepts have the potential of significantly improving the probability of detection and classification of buried objects. On the other hand the potential of such sonar systems is dependent on development of model-based, multistatic imaging concepts which explore the different physics and spatial properties of target scattering and reverberation in shallow water waveguides. The fundamental physics of multistatic seabed acoustics is poorly understood, and the development of such knowledge, and the associated improved multistatic modeling capability is the central objective of this project.

APPROACH

To address the significance of the various environmental features affecting the bottom target sonar performance, MIT is developing a modeling framework with consistent

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treatment of seabed elasticity, seabed interface roughness, volume inhomogeneity, and the waveguide physics. The centre piece of this modeling framework is the wavenumber integration approach of OASES/SAFARI for solving the wave equation in stratified media.

To achieve a more complete description of realistic shallow water environments the base models are modified and expanded. For example, various possibilities are pursued for including seismo-acoustic range-dependence and mode conversion to the capabilities of OASES/SAFARI [1]. In addition, to allow modeling of 3-D, multi-static roughness reverberation, the roughness perturbation formulation of Kuperman and Schmidt has been modified to model reverberation from anisotropic roughness patches in a stratified shallow water environment [2]. This modeling capability allows for detailed analysis of the relative importance of roughness characteristics, bottom stratification and bottom elasticity in shaping the spatial characteristics of the reverberant field, and as mechanisms for subcritical penetration.

The target scattering is modeled in a consistent manner. Using an approach similar to the one of Ingenito [3], the object scattering function is convolved with the incident field computed by a standard spectral propagation model, here OASES, to yield a virtual source, which is then implemented in a propagation model for computing the total waveguide scattering response. Here, the use of the 3-D version of OASES [4] allows for very efficient computation of the full azimuthal field distribution in stratified waveguides, for the targets as well as the seabed roughness reverberation.

Ultimately the effort will provide a consistent, physics-based modeling capability for use in the design of new robust and accurate multi-static sonar processing concepts.

ACCOMPLISHMENTS AND RESULTS

Previously, a perturbation formulation for 3-D scattering from rough elastic interfaces has been modified to handle roughness patches of finite size, and implemented into OASES to yield a spectral formulation of the bistatic reverberation from anisotropic roughness patches in a stratified elastic seabed [1]. In 1997, this modeling capability has been successfully validated by comparison to other scattering theories for the simple two halfspace problem. The comparison to the in-plane, bistatic scattering strength results generated independently by Dorfman [5,6] for scattering off a basalt seabed, assuming the basalt to be a fluid medium, is shown in Fig.1. This figure also shows the scattering strength for the same problem, but with the basalt being represented by an elastic medium. The enhanced backscattering observed for the elastic bottom is consistent with the ARSRP observations [5,6].

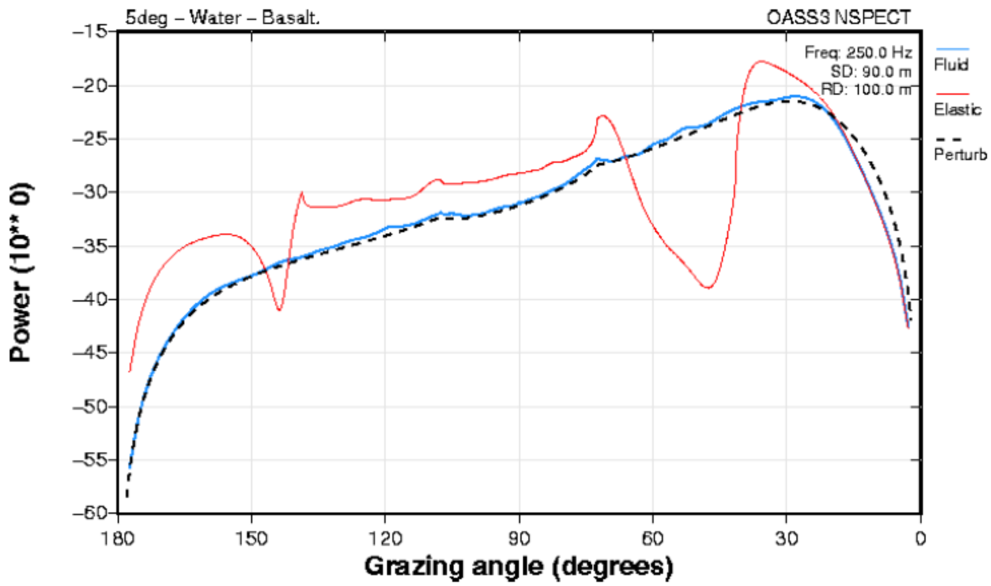

Figure 1: In-plane scattering strength - comparison with analytic perturbation solution.

In 97 the 3-D OASES modeling framework has been expanded with two 3-D target models. The simples target model is that of a sphere, and here the scattering function is given in terms of spherical harmonics [2]. The formulation of Ingenito has been extended to handle evanescent incident and scattered fields associated with buried targets. Another more complex target model uses the theory of Rumerman [7] with the extensions of Ricks [8] to compute the anisotropic scattering function for a finite cylindrical shell in a fluid background. This formulation is in the process of being extended to handle buried target scattering at subcritical incidence as well. Fig 2 shows an example of the azimuthal depence of the scattered field at 3 kHz in the water column for a cylindrical target (L = 2m, a=0.5m) at 45 degree aspect relative to the incident field. The target is suspended 0.5 m above the seabed in 10 m of water, and the field is computed in a horizontal plane at 90 m depth.

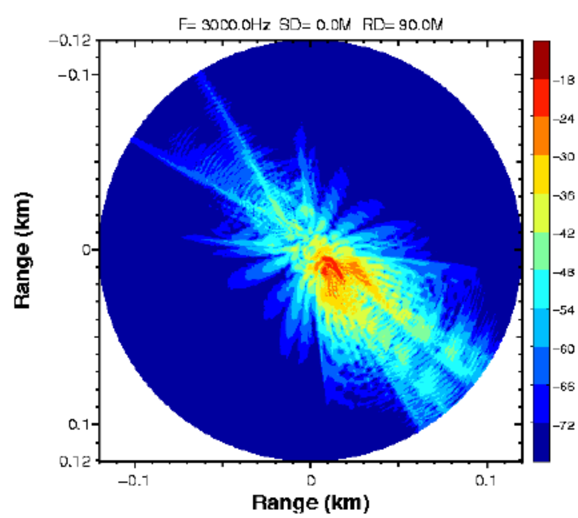

Figure 2: Scattering field from 45deg slanted steel shell (L=2m, R=0.5m, T=5cm)

Currently a major part of the effort is devoted to the planning of an experiment, GOATS`98, which has as it's overall objective to validate the current multistatic modeling capabilities [9]. This experiment will be carried out in the Mediterranean in May 98, in collaboration with the

MIT Sea Grant AUV Laboritory and SACLANT Undersea Research Centre. Two Odyssey class AUV's will be used as mobile acoustic platforms together with a suite of fixed acoustic arrays for measuring the spatial distribution of the target scattering and anisotropic seabed reverberation in shallow water in the medium frequency range, 1-10 kHz.

TRANSITIONS

In addition to serving as a tool for the multi-static reverberation modeling, the OASES code, already in wide-spread use in the underwater acoustics and seismic community, has continued to be upgraded in 1996. The newest export version (2.1) of OASES is available on the World Wide Web (ftp://keel.mit.edu/pub/oases/). In addition to upgraded versions at most US Navy laboratories and ONR sponsored universities in the US an Canada, installations in 1997 include universities and laboratories in Taiwan, South Korea, Singapore, Japan, Russia, Germany, Norway, Italy, Sweden, and Denmark, among others.

As part of the collaborative effort with SACLANTCEN on GOATS`98, the 3-D target and seabed scattering models have been transitioned to SACLANTCEN, where they are applied in the experiment planning and for analysis of past experimental data associated with sub-critical penetration.

RELATIONSHIP TO OTHER PROJECTS

There is significant joint effort between this project and the ONR Sea Ice Mechanics (SIMI) effort, the Haro Strait Frontal Dynamics PRIMER, and the ARSRP, in particular in terms of the model development and application.

Currently, there is a strong relation to the ONR MURI: Autonomous Oceanographic Sampling Networks (AOSN). The AUV component of the GOATS`98 experiment is funded in part by SACLANTCEN, but primarily through the MURI (Curtin).

Also, the modeling effort has a close relationship to the NOPP 'Littoral Ocean Observation and Prediction System' (Harvard, MIT et al., Curtin), of which PI is a partner in charge of all acoustic modeling efforts.

This effort is also closely related to the High-Frequency DRI (Thorsos, Simmen) in terms of objectives and experimental plans and procedures. However, the DRI has it focus at frequencies above 10 kHz, while the present effort is aimed at the mid-frequency, 1-10kHz regime.

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